THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. VI. ANN ARBOR, MAY, 1889. No. 1.

ORIGINAL ARTICLES.

MEETING OF THE NEW ENGLAND METEOROLOGICAL SOCIETY.

The fifteenth regular meeting was held at Worcester, Mass., April 16, 1889, and the following are abstracts of the papers read:

LIGHTNING AND THE ELECTRICITY OF THE ATMOSPHERE.

BY A. G. MCADIE, M. A.

Lightning is essentially electricity of high potential. Potential is a convenient term to express a certain force relation. It is not electrical force. That arises when the potential of a body differs from that of another. When the potentials of bodies are the same there is no electrical force; furthermore, the direction of electrical force is always from the place of higher to the place of lower potential, and the rate of variation of the potential measures the component force in that direction. Franklin's famous kite experiment in reality only proved that a difference of potential did exist between the clouds and the ground. This, of all Franklin's experiments, is the most famous, because it was accepted at once as conclusively proving the general identity of lightning and the electricity developed by the friction machines of that time. But, we must not forget that other experiments were made by Franklin, and that the famous kite experiment was but one in a series.

The kite experiment, under modern auspices, was tried a few summers ago at the Blue Hill observatory, near Boston. The summit of the hill has an elevation of 635 feet above sea-level, and is the highest point on this section of the Atlantic seaboard. We differed from Franklin in being able to ascertain the value of the potential at each step. Our first step was to ascertain the value of the potential of the air a few feet out from the observatory walls and about five feet above the ground. Then, having flown the kite (a large light silk-covered kite, the longest axis over four feet and tin foiled on the front face), the wired kite-string was connected with the electrometer and direct measurements of the potential made. The moment the kite-string, properly insulated, of course, was put in connection with the needle (a technical name for a light disk of aluminum which is free to move between two sets of metallic conductors which have different electrical potentials) of the electrometer, the needle was deflected with a considerable impulse beyond the scale limits, indicating a very high positive potential for the air in the vicinity of the kite. All of one forenoon the sky was covered with a low pallium of dark stratus clouds and the weather threatening, and yet the deflections were just the same as later on, when the weather had cleared up and developed into a clear and pleasant June afternoon. On one morning the wind was quite "puffy," and consequently our kite, after we had succeeded in flying it, was not at all steady, and kept falling and rising. Without exception, when the kite would rise, the needle would indicate an increase in the value of the potential, and the sparks would be longer and more frequent, while on the other hand, as regularly as the kite fell, the deflection decreased. At another time we made experiments when the sky was without clouds and with the kite about 400 feet above the ground, the sparks we obtained on "grounding" the kite wire were thick and in length about one-eighth of an inch; these under a perfectly cloudless sky.

It is a surprising fact that, with the great number of experiments that were made by the large number of able workers contemporaneous with Franklin, no very marked advance upon his

experiments occurred during the 40 years succeeding, and it was not until the beginning of the nineteenth century that attempts at systematic observations of atmospheric electricity and weather elements were made.

Perhaps the most interesting observations on the character of lightning were some made at the top of the Washington monument, elevation 500 feet above the city streets, during thunder-storms. On July 14, 1886, a thunder-squall came up suddenly. Negative deflections indicated a potential difference between the air at the monument and the ground of 3,000 volts, or, in other words, there was the same difference as between the first positive and final negative pole of 3,000 Daniel cells connected in "series." Sparks passed almost continuously between the suspending wire and the case of the electrometer. The "sparking" between the collector and ground ceased, and, as we afterwards found out, when thunder clouds approach the electrometer needle responds to their presence and is very active, and after considerable oscillation begins to move steadily in one direction as if subject to a steadily increasing pull, and then, when perhaps a potential of several thousand volts is reached, a sudden drop to zero occurs, and with it the flash of lightning. Then the needle begins again to move steadily, and repeats the same operation with every flash of lightning. And it is both possible and not difficult, in this way, to know just when a flash of lightning is going to occur, and to prepare the camera (if we are taking photographs). This at least is one feature, we think entirely new, and brought out by these experiments and observations.

It is a common experience with surveying parties, especially on western mountain peaks, to undergo peculiar sensations during thunder-storms. These effects consist in general of a hissing, crackling sound, accompanying single discharges, or more marked sparks, with a tingling sensation if a finger be presented to any metallic object near by. Now it has been several times observed that a sudden cessation of these distressing electrical effects was experienced whenever there occurred a flash of lightning. We see an explanation for this in what precedes,

and our electrometer measurements prove to us without doubt that every lightning flash relieves the electrical tension, besides enabling us to measure the electric strength of the air under ordinary conditions, and the electro-motive force producing the disruptive discharge.

Finally we come to the effects of the electrification of the air upon water, dust and other particles in it. Whenever our collector was "grounded," the fine stream of water issuing from it would preserve a certain even, rounded character, breaking into drops some four inches away from the place of exit. Removing the "ground" connection, and the stream being now under the influence of the thunder-clouds, the steadily increasing electrification of the air caused the stream to twist and split with innumerable threads and sprays; but with the flash of lightning the distortion ceased to exist, and the stream resumed its first and proper character, only to be again distorted and to repeat the operation with each flash of lightning. Here is a cheap and easy mode of foretelling the lightning, and the photographer has now at his hand warning for his exposure.

REPORT ON THE INVESTIGATION OF THE SEA-BREEZE.

Professor W. M. Davis made a report on the investigation of the sea-breeze undertaken in 1887. The observations made by volunteer observers of the Society were under the direction of Mr. L. G. Schultz of the U. S. Signal Service. The 100 stations were chiefly in Massachusetts, but some were in southeastern New Hampshire. There were inland as well as coast stations, in order to show the general wind and its modification by the sea-breeze. Observations were requested at 1 and 4 P. M. daily and hourly on "storm days," which were appointed when it was expected there would be faint gradients about anti-cyclonic areas which would be favorable for the development of the sea-breeze.

The synoptic method of study of the data was used, that is, charts were constructed to show the conditions prevailing at all stations at the hours of observation. From these it was found that at about 10 A. M. the sea-breeze began to blow normally to

the coast. Later in the day it penetrated further inland on the North Shore (N. of Boston) than on the South Shore. It is suggested that this results from the deflection of the general easterly breeze, by the earth's rotation, into a southeasterly breeze, thus throwing the movement of the air nearly parallel to the South Shore but square with the North Shore. The inland extension of the sea-breeze from the Rhode Island coast may coöperate to the same end. Another curious fact is that the diurnal range of temperature, which is diminished on the coast by the action of the sea-breeze, is not lessened at the inland stations. This seems remarkable since the motion of the sea-breeze inland is thought to be due to the difference of temperature between land and sea. But, although the sea-breeze is apparently heated up to the temperature of the land-breeze at inland stations, this may be only in its lower layers.

The general theory that the sea-breeze is caused by the difference of temperature between the land and water requires the breeze to begin at the shore and extend its area seaward, while observation shows that the breeze begins out at sea and works its way in shore. This was first noticed by Dampier, and has repeatedly been confirmed. Following Seemann it may be explained by supposing that the circulation of the air is not established, but is in process of establishment, and that the quick morning expansion of the land air causes a reverse gradient at the shore line, turning the surface winds toward the sea. This gradient disappears as the expansion of the air causes an upper outflow, and then the inland progress of the sea-breeze is effected. There should in this case be a difference of barometric pressure at land and sea stations, and such observations of pressure and temperature have been made by Blanford in India. The depth of the sea-breeze was determined by balloon observations at Coney Island to be between 300 and 400 feet.

On mountainous islands the diurnal valley-breeze is confirmed by the sea-breeze. The diurnal change in the wind's direction at coast stations is explained by the combination of the land and sea-breezes deflected by the earth's rotation. In our hemisphere this rotation is from the east, through the south, to the

north. At New Haven, on the southern coast of New England, the effect is to give a more southerly wind at noon, which is more marked in summer than in winter. At Hudson, near the south shore of Lake Erie, the day wind has a tendency to become northerly, and at Toronto, on the north side, the day wind turns to the south.

THE PRACTICAL VALUE OF SELF-RECORDING RAIN-GAUGES.

By Edmund B. Weston, C. E.

What are the uses of self-recording meteorological instruments, is a question that is frequently asked. This question may be readily answered by saying that it is very generally conceded at the present time, that they are absolutely essential for an intelligent study and comparison of meteorological phenomena. With an ordinary rain-gauge, it is impossible to determine the rate per hour of the fall of rain during a storm without noting the time that it is raining, with a watch, and as it is very inconvenient in the majority of cases to do this, it is very rarely done, and when it is, an average rate is all that is generally obtained, although it may heve been raining faster or slower at intervals during the time noted. By the use of a reliable self-recording rain-gauge, the different rates that rain has fallen during a storm can be readily determined. The writer was under the impression before he commenced to study the diagrams of self-recording gauges, that a rate of rainfall of one inch per hour was of very unusual occurrence; a short experience with them however, dispelled this idea. Tables have been compiled from diagrams taken from the self-recording rain-gauges of the Draper pattern that were operated under the direction of the City Engineers' Department at the different stations in Providence, R. I., and its environs. The data of the seven warm months from April to October, have only been included in the tables, as during the cold months the pipe of each rain-gauge, which connects the funnel that receives the rainfall with the recording apparatus, at times, gets clogged with ice or snow, consequently there is often a question of doubt during these months as to the reliability of the recorded rates.

It has been a great source of trouble to many civil engineers during the last few years, when so many sewerage systems have been designed and built, to obtain reliable and useful rain-fall data, in order to determine what sizes of sewers will be required to provide for the whole, or a portion of the rainfall, of the localities under consideration. The majority of meteorological records are of very little use in this respect, as generally it is only possible to obtain from the best of them, the depth of rain, the date of the storm and the time when it commenced and ceased. The writer was only able to find in one of the most reliable meteorological records in the country, indications of 11 times during 40 years when it had rained at a rate of one inch per hour or more, but the data obtained at Providence, shows that during nine years there were 41 times when it rained at the rate of one inch per hour or more at one or more intervals during the storms that occurred in this period. In the case of the sewer of a compactly built city, it can be assumed, more especially in this part of the country, that the amount of sewerage will be very small in proportion to the amount of rainfall, and that all the rain when falling at excessive rates will be conducted into the sewer as fast as it falls, and that the sewer would probably be flowing full before 0.2 of an inch of rain had fallen.

As an example of the value of self-recording rain-gauges for the purpose of studying local rain storms, the writer would call attention to a remarkable storm that occurred August 6, 1878, when the amount of rain that fell per hour, was and is without precedent in Providence. At one station the duration of the rain was one hour, and the total depth that fell within this hour was 4.49 inches, but during a portion of the time 3.50 inches fell at the rate of 5.83 inches per hour. Many more instances could be mentioned relative to the value of self-recording rain-gauges in which their diagrams have played an important part, such as substantiating testimony in courts of law, as well as in furnishing much valuable information for many other purposes.

DIAGRAMS ILLUSTRATING EVAPORATION.

Mr. Desmond Fitzgerald exhibited some recent diagrams of evaporation from a water surface taken from his self-recording

instrument in use at Chestnut Hill Reservoir of the Boston Water Works. A full description with plates illustrating the apparatus has already been published in the transactions of the American Society of Civil Engineers. The tank, 10 feet in diameter, floats in the reservoir surrounded by a large raft, and the losses from the water surface are recorded automatically by means of a float and clockwork arrangement. Mr. Fitzgerald exhibited the diagrams to demonstrate that the maximum evaporation of half an inch from a large water surface in this latitude was not as rare an occurrence as he had once thought. The speaker referred to some of the laws of evaporation, calling attention to the close relation of the temperature curve to the evaporation curve for the year. The maximum rate generally obtains after a long heated period followed by a sudden cool wave which lessens the absolute humidity force in the air.

ANEMOMETER COMPARISONS.

By Professor H. A. Hazen.

Since the preparation of a paper on this subject published in the March Journal, several points of some interest have arisen which demand attention. In justice to Prof. Marvin I must say that the suggested explanation of the effect of a free wind upon an anemometer on a whirler was not obtained from him in so many words, but I inferred that that was his view from our conversations. A careful study of the question shows that the statement needs a slight modification, without changing in any way, however, the ultimate resultant effect.

The simplest form of regarding the question is to think of an anemometer carried upon a train, leaving out of consideration any outside effects produced by eddies, "mitwind," etc. Suppose the wind is moving toward the train, it is very plain that the resultant effect on the anemometer would be the sum of the two. Let a = motion of train, b = wind and r = resultant, we have $r = a + b$. Now if $b = 2a$, we see that r is produced, $\frac{2}{3}$ by the wind and $\frac{1}{3}$ by the train; if $b = a$, r is due $\frac{1}{2}$ to each; if $b = \frac{1}{2}a$, r is made $\frac{1}{3}$ by wind and $\frac{2}{3}$ by train, and so on. In con-

sidering the effect of an uniform wind at any angle we must bear in mind that its action is continuous and relatively exactly proportional to its velocity. The same is true in the case of the whirler and wind, where the wind is constant and the arm takes various angles with it. For example, if the wind and whirler velocity are equal, half the resultant will be due to each in all parts of the whirl.

This resultant will have a continuous increase for one-half the rotation of the whirler and an equal retardation during the other half. The determination of this resultant involves the solution of a triangle in which two sides and included angle are given. The two sides are the motion of the whirler (a) and wind (b), the included angle (C) is that between the wind and the arm of the whirler, the side (c) opposite (C) is the resultant sought. One of the simplest solutions is that given in Loomis' Geometry, p. 314, namely,

$$\cos C = \frac{b^2 + a^2 - c^2}{2ba}$$

or

$$c = \sqrt{b^2 + a^2 - 2ba \cos C}$$

Assume $a = 16$, we may compute c for several values of b and C, as in the following table.

TABLE I.—VALUES OF c.

$b = 32$		$b = 16$	$b = 8$	$b = 4$
C	c	c	c	c
0°	16.0	.0	8 0	12.0
30	20.2	8.3	9.9	12.7
60	27.9	16.0	13.9	14.4
90	34.0	22.6	17 9	16.5
120	42.2	27.7	21.2	18.3
150	47 0	30.9	23.3	19.6
180	48.0	32.0	24 0	20.0

TABE II.—$a = 16$.

b	C
32	0° 0′
16	60 0
8	75 31
4	82 49
2	86 25
0	90 00

Table II gives the value of C at which the resultant effect of both wind and whirler exactly equal the whirler motion when there is no wind. If we sum the resultants in Table I at all values of b we shall find an increase of nearly 100 per cent. due to the wind above the whirler when $b = 2a$, and this increase is continuous for the whole rotation; when $b = a$, the increase is 25 per cent., and continues for $\frac{2}{3}$ of the rotation; when $b = \frac{1}{2}a$ the increase is ten per cent. for $\frac{1}{12}$ of the rotation and so on. It seems probable that when there is added to this the effect of whirls, all of which would tend to increase the anemometer motion and hence diminish the factor, the low values found in England would be accounted for.

An interesting question has arisen regarding the probable effect of the momentum of heavy cups when placed on the whirler. With a radius of 17 feet, at a velocity of 30 feet per second, it would take less than two seconds to complete a half revolution. Why might not there be an acceleration in each rotation, due to the momentum of the cups, slightly above the motion of the whirler. On examining Table I, however, we see that the increase on which this effect depends continues for just half the rotation and is balanced by the diminution in the other half. Moreover, this hypothesis does violence to the commonly accepted view that in an intermittent wind the heavier cups would lag behind while it rises and falls, but the resultant indicated motion would practically be that of the wind. As a matter of fact it would appear as though in a very gusty wind the lighter cups would forge slightly ahead of the heavier. During the experiments with the paper cups already published in the first article it was seen that often the very light cups would nearly come to a stand-still while no such effect was noted in the heavier cups. A set of cups was made of paper, cone shaped with a diameter of four inches and height of 2.4 inches. The weight was about $2\frac{1}{2}$ oz., while the spherical cups with which they were compared weighed 16 oz. The arms were round and about $\frac{1}{16}$ inch in diameter; all the other parts were exactly the same in both instruments. In comparisons on March 23 and 25 the lighter cups gave about 16 per cent. less wind than

the heavier. On March 24 the paper cups were weighted with lead at the end of the arm to four times their former weight, and the result was the same as before. This showed that the momentum of the heavier cups had no effect upon the average motion, but the cone cups could not be directly compared with the spherical, though of the same size. Spherical shaped paper cups were then made like the metallic, except a slight roughness on the exterior, which would tend to make them give less motion. The comparisons for three weeks have shown the lighter cups faster from two to four per cent. in light winds and no difference in the higher winds. There was also a slight tendency for the paper cups to give a higher velocity with the more intermittent winds.

The explanation given in the first article for the uniform results obtained with the helicoidal anemometer seems borne out by these later experiments. The tendency would be for the vane to place itself normal to the arm, and before the free wind could overcome this the arm would move to another portion of the whirl, where the wind would tend to move the vane in the opposite direction.

April 19, 1889.

Note, added April 29th.

Since writing the above, a paper has appeared on the same subject in the last JOURNAL, and as there seem to be contradictions between that work and mine, I desire to call attention to one or two points farther. On p. 553 I find "the resultant force acting on the cups when the velocity of the wind is increasing and tending to increase the velocity of the cups, is much greater than the corresponding force in action when the wind is diminishing in intensity, and which tends to retard the velocity of the cups." Is not this dangerously near the much sought after "perpetual motion"? While the resistance of the air is much less on the convex side in a declining motion, yet it is evident that there will be practically about four convex surfaces retarding motion in this case, while there would be only about three in an increasing motion. This will be specially evident in the case

where we imagine the wind to give an impulse to the cups and then entirely cease. In no case whatever can we consider that the ultimate motion would be greater than in an uniform wind, but somewhat less. The Robinson anemometer is by far the best instrument ever devised for variable winds, and I do not think the results vary more than a few per cent., and the motion must always be slightly too small.

It seems to me that if the results given in the tables on pp. 560 and 561 are rightly interpreted, they prove all this. It should be noted that in comparing anemometers in a variable wind, it is necessary, in order to obtain at all satisfactory results, to expose them for an hour or more in order to eliminate accidental errors. Of course, it would be a very simple matter to pick out a two-minute velocity which would show 15 to 20 per cent. greater for the heavier cups, provided that was taken when the wind was diminishing, while the average velocity would show no such effect. For example, in Table V, the average higher reading of the heavy cups, with a wind about 5 miles per hour, was 7.6 per cent., while in individual cases with about the same velocity, this ran up as high as 23 per cent., and in one case the heavier cups actually gave a less velocity by 0.6 per cent. The crucial test, however, to disprove this theory is found in the fact that the heavier cups, weighted perhaps to two or three times the original weight, gave almost identical results, in the average winds, with the lighter cups.

It seems to me the explanation of the peculiar results, found by Prof. Marvin, lies in the fact that the very small cone-shaped cups, weighing, with the arms, less than $2\frac{1}{2}$ grams, were very much retarded in the roof experiments as compared with those on the whirler. This may have been due to a very different effect of the variable wind over the uniform motion of the whirler. In the experiments described in my first paper, two of the anemometers showed a difference of 29 per cent. between the uniform motion and the variable wind. It is possible that the conditions of exposure, or of the instrument, were not the same in the two sets of experiments. I do not think it can be possible that the momentum of the cups had any appreciable effect.

TORNADOES IN ILLINOIS.

STATE TORNADO CHARTS.—ILLINOIS.

By LIEUT. JNO. P. FINLEY, Signal Service, U. S. A.

TABLE I.—*Tornadoes in Illinois.*

Period of observation, 54 years, 1835-1888.
Total number of storms, 141.
Year of greatest frequency, 1886,—21 storms.
Month of greatest frequency, May,—53 storms.
Day of greatest frequency, May 18th,—11 storms.
Hour of greatest frequency, 4 to 5 P. M.
Months without storms, none.
Prevailing direction of storm movement, NE.
Region of maximum storm frequency, central and northwest portions.

TABLE II.—*A Chronological Table, showing the location, date, and time of occurrence and general character of formation and movement of Tornadoes in the State of Illinois for a period of 54 years, from 1835 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Fulton	June 18.	1835				
Fulton	June 19.	1835	9 p. m.	S 70° E.		2,640.
Rock Island and Whiteside	June 5.	1844	5 p. m.	ESE.		1,300 to 1,600.
Cass		1845				1,320.
Washington	June —.	1846		NE.		
Peoria	June —.	1847	3 p. m.	S 70° E.	Funnel.	
Menard	May 27.	1849				
Kankakee	June 23.	1854				
Cook	May 22.	1855				
Warren	May 30.	1858	5 p. m.	NE.	Funnel.	660.
Warren	June —.	1858	Afternoon.	S 60° E.	"	
Morgan	May 26.	1859				
Morgan	May 29.	1859	4:40 p. m.			
Mercer, Henry, Lee, DeKalb, Kane and Cook	May 30. ?	1860				
Whiteside	June 3.	1860	5 p. m.	NE.	Funnel.	800.
Champaign		1860		ESE.		
Madison	March 27.	1861	7 p. m.			
Washington	November 8.	1864	12 m.	NE.		150.
White	May 22.	1868	4 p. m.	NE.		
Washington	July —.	1868		E.	Funnel.	
Whiteside	April 18.	1869	Afternoon.	NE.	"	
Washington	July 13.	1870				1,320.
Madison	Summer.	1870				
St. Clair	March 8.	1871	3 p. m.			
Sangamon	June —.	1871				
Adams	May 20.	1872	7 p. m.	E.	Funnel.	
Warren	May —.	1873				
Warren	May 23.	1873	4 p. m.	E 20° S.		660.
Alexander	March 18.	1874	4 a. m.	NE.	Local whirlwind.	
St. Clair	June 18.	1875				
Union	June 21.	1875				
Peoria	August 5.	1875	6 p. m.			
Knox	August 5.	1875	5 p. m.	NE.		1,000 to 1,200.
DeKalb	August 5	1875	7:20 p. m.	NE.		
Lee	August 5.	1875	Afternoon.	SE.	Funnel.	
McLean	September 9.	1875	Evening.	NE.	"	
Rock Island	January 1.	1876	3 p. m.	SE.		

TABLE II.—*Continued.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Madison	February 27.	1876	3 p. m.	NE.		
Union	May 6.	1876	9:30 p. m.	NNE.	Funnel.	200 to 1,500.
Jackson	May 6.	1876	9:30 p. m.	SE.	"	
Cook	May 6.	1876	5:10 p. m.	NE.	"	
Washington	July —.	1876	8 p. m.	SE.		50.
Hancock	December 8.	1876	9 a. m.			
Clark	March 20.	1877	6:40 p. m.	E.	Regular whirlw'd.	66 to 99.
Wabash	June 4.	1877	4:30 p. m.	ENE.	Funnel.	150 to 1,200.
Coles	June 4.	1877	4:45 p. m.	NE.	"	80 to 200.
DeWitt	August 14.	1877	Afternoon.	NE.		3,000.
Alexander	April 23.	1878	4:10 a. m.			
Cook	May 23.	1878	6 p. m.	NE.	Funnel.	
Brown	May 23.	1878	6 p. m.	SE.	Inverted cone,	200 to 400.
Adams and Brown	May 23.	1878	6:30 p. m.	SE.		
Grundy	May 31.	1878	Afternoon.	NE.		
Macoupin	March 10.	1879	Afternoon.	NE.	Funnel.	1,500 to 2,500.
Madison	April 14.	1879	2:45 p. m.	ESE.	"	1,200.
White	June 10.	1879	Afternoon.		"	
Alexander	November 14.	1879	1 p. m.			
Whiteside	April 18.	1880	Afternoon.	NE.	Funnel.	
Madison	April 18.	1880	Afternoon.			
Macon	April 18.	1880	Afternoon.			
DeWitt	April 18.	1880	Night.			
Bond	April 18.	1880	Afternoon.			
Douglas	April 19.	1880	2 a. m.			
Sangamon	April 24	1880	10 p. m.	NE.	Funnel.	
Macoupin	April 24.	1880	6:30 p. m.	NE.		
Christian	April 24.	1880	7 p. m.	NE.	Funnel.	800 to 2,500.
Adams	April 24.	1880	7:30 p. m.		"	2,000 to 3,000.
Bureau	April 24.	1880	6 p. m.	NE.		2,640.
Morgan	May 8.	1880	8 p. m.			
Scott	May 10.	1880	7 p. m.	NE.	Funnel.	
Morgan	May 10.	1880		NE.		
Morgan	May 10.	1880	9 p. m.	NE	Funnel.	1,000 to 1,300.
McLean	May 10.	1880				
DeWitt	May 10.	1880	Evening.	NE.		
Jackson	May 20.	1880	2 p. m.	NE.		
McHenry	September 3.	1880	Afternoon.	NE.	Funnel.	100 to 300.

TABLE II.—*Continued.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Randolph	May 14.	1881	.....	NE.	.....	.....
Union	June 2.	1881	Afternoon.	.....	.....	.....
Montgomery	June 29.	1881	5 p. m.	NE.	.....	.....
Schuyler	September 24.	1881	5 p. m.	NE.	Funnel.	.....
Rock Island	"	1881	4 p. m.	NE.	.....	1,500 to 2,000.
Marian	"	1881	4:30 p. m.	NE.	.....	.....
Adams	"	1881	5 p. m.	NE.	.....	.....
Adams	"	1881	5 p. m.	NE.	Funnel.	5,000 to 8,000.
Kendall	September 29.	1881	Afternoon.	NE.	.....	.....
Schuyler	October 8.	1881	.....	.....	.....	.....
Jersey	April 24.	1882	5:30 p. m.	E.	.....	2,640.
DeWitt	June 17.	1882	.....	NE.	"Whirlwind."	.....
Washington	May 18.	1883	11 p. m.	NE.	.....	100.
Sangamon, Logan and DeWitt	"	1883	7:30 p. m.	NE.	Funnel.	450.
Morgan and Cass	"	1883	8:15 p. m.	NE.	"	330 to 660.
Morgan	"	1883	.....	.....	.....	.....
Menard and Logan	"	1883	9:30 p. m.	.....	.....	.....
Madison and Montgomery	"	1883	.....	NE.	Funnel.	165 to 660
McHenry	"	1883	6 p. m.	NE.	Inverted cone.	330 to 1,320.
Macoupin and Montgomery	"	1883	9:30 p. m.	NE.	.....	.....
Livingston	"	1883	9:15 p. m.	NE.	.....	660.
Jersey	"	1883	8:15 p. m.	NE.	.....	.....
Greene and Macoupin	"	1883	6:20 p. m.	NE.	Funnel.	.....
Piatt	May 19.	1883	12:15 a. m.	NE.	.....	.....
McHenry	May 25.	1883	6:30 p. m.	NE.	Funnel.	330 to 660.
Morgan and Sangamon	June 8.	1883	About 5:30 p. m.	NE.	"	150.
McHenry	June 11.	1883	5:30 p. m.	.....	.....	300.
Madison	March 25.	1884	6 p. m.	SE.	Funnel.	.....
White	November 6.	1885	4:45 p. m.	N 45° E.	"	330 to 1,320.
Warren and Mercer	"	1885	4:20 p. m.	NNE.	"	2,640.
Peoria	"	1885	5:45 p. m.	NE.	"	82.
Pike and Brown	"	1885	3:15 p. m.	NNE.	"	150 to 450.
McHenry	May 6.	1886	2 p. m.	NE.	"	.....
Carroll	May 12.	1886	6 p. m.	NE.	"	.....
Livingston	"	1886	3:45 p. m.	NE.	"	1,800.
Vermillion	"	1886	Afternoon	NE.	"	450.
Vermillion	"	1886	5:20 p. m.	N 80° E.	"	2,640.
Vermillion	"	1886	5:05 p. m.	ENE.	"Column."	660.

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
McLean	May 12.	1886	6:45 p. m.	NE.	Funnel.	.....
Vermillion	"	1886	3 p. m.	E.	"	.....
Winnebago	"	1886	5:30 p. m.	NE.	"Basket."	2,640 to 5,280.
Randolph	May 11.	1886	2:30 p. m.	NE.	Funnel.	1,320.
Vermillion	May 12.	1886	5 p. m.	NE.	"	1,320 to 2,640.
Brown	May 13.	1886	5:30 p. m.	NE.	"	.....
Morgan	"	1886	6:45 p. m.	E.	"	.....
McLean	July 9.	1886	7:30 p. m.	Easterly.	"	.....
Shelby	September 16.	1886	11 a. m.	NE.	"	.....
Champaign	"	1886	4 p. m.	ESE.	"	.....
Sangamon	"	1886	4 p. m.	NE.	"	.....
Champaign	"	1886	4 p. m.	NE.	"	.....
Champaign	"	1886	4 p. m.	NE.	"	660.
Douglas	"	1886	About 6 p. m.	NE.	"	.....
Will	September 18.	1886	7:15 p. m.	NE.	"	50 to 300.
White	April 22.	1887	11:45 p. m.	NE.	"	Narrow.
Wabash	"	1887	6 p. m.	NE.	"	210 to 1,320.
Perry	April 29.	1887	6 a. m.	Easterly.	"	180 to 210.
Jo Daviess	July 13.	1887	Evening.	NE.	"	.....
Shelby	August 4.	1887	1:50 p. m.	Easterly.	"	60 to 300.
Sangamon	September 4.	1887	4 p. m.	NE.	"	2,640.
Randolph, Perry, Washington and Jefferson	February 19.	1888	2:30 to 5 p. m.	NE.	"	250 to 2,640.
Perry	April 22.	1888	5 p. m.	E.	"	Narrow.
La Salle	May 3.	1888	Evening.	Easterly.	.....	"
Stephenson	May 11.	1888	Evening.	Easterly.	Funnel.	"
Saline	June 7.	1888	3 p. m.	NE.	"	.....
Vermillion	July 29.	1888	5 p. m.	NE.	"	600.
Henry	August 16.	1888	4 p. m.	NE.	"	2,240.

TABLE III.—*Relative frequency of Tornadoes by months and days, for Illinois.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January	1,	1	1
February	19, 27,	2	2
March	8, 10, 18, 20, 25, and (—),	6	6
April	14, (18)^{6}, 19, (22)^{3}, 23, (24)^{6}, and 29,	7	19
May	3, (6)^{4}, 8, (10)^{5}, (11)^{2}, (12)^{9}, (13)^{2}, 14, (18)^{11}, 19, (20)^{2}, (22)^{2}, (23)^{4}, 25, 26, 27, 29, (30)^{2}, 31, and (—),	20	53
June	2, 3, (4)^{2}, 5, 7, 8, 10, 11, 17, (18)^{2}, 19, 21, 23, 29, and (—)^{1},	15	20
July	9, (13)^{2}, 29, and (—)^{2},	4	6
August	4, (5)^{4}, 14, and 16,	4	7
September	3, 4, 9, (16)^{6}, 18, (24)^{5}, and 29,	7	16
October	8,	1	1
November	(6)^{4}, 8, and 14,	3	6
December	8,	1	1
(—) Blank	(—)^{4}	1	3
Total		72	141

NOTE.—The blank (—) signifies date missing.

VERIFICATIONS AT THE SIGNAL OFFICE.

The Chief Signal Officer has kindly placed in my hands the official instructions for the preparation of the indications and those for their verification. These are the latest instructions, issued August 1, 1888, with an amendment regarding "cold waves" issued January 5, 1889. I have selected from these instructions such as would guide any one in ascertaining the method employed by the Signal Office in estimating verifications, adding a few others of general interest, though not necessary for this purpose. The original paragraph numbers are preserved, and from them it is easy to judge how much has been cut out. It generally relates to office details.

It may be of interest to the public to know that the indications are intrusted to a special officer detailed for that purpose, and that this detail is usually changed monthly. The "Indications Official" can call on any one about the office for counsel, but is himself responsible for his predictions, the verification of which is made out at the end of the month. As I understand it, a special officer, Professor Russell, is in charge permanently of the cold wave predictions, and another, Professor Marvin, of the verifications. The latter is not called on to make predictions and is thus left free from bias,—a feature very desirable where so much is left to the judgment, and when the success or failure of other officers is officially weighed.

I also think it proper to say that the lower average of verifications of late years as compared with the early years of the Service is due to increased precision and care in estimating the verifications.

M. W. H.

INSTRUCTIONS FOR PREDICTIONS.

14. The official will avoid doubtful or ambiguous expressions and double predictions as far as possible. Whenever double predictions are used, he must state definitely the day of the week on which the atmospheric conditions predicted are expected to occur. The day of the week will be frequently used in making single predictions, and the official is encouraged to omit the first part of the predictions when he feels confident of being able to predict for the last twelve hours. For instance, if on Monday morning the official feels confident that rain will occur on Tuesday, he can avoid the Monday prediction entirely, and say rain on Tues-

day, or if rain is falling and he is certain of fair weather on Tuesday, he will predict fair weather.

16. Whenever he has failed to predict the advance of cold waves or dangerous storms to any locality, he will refrain from ordering signals or sending special dispatches, unless he believes that such warnings will arrive at least four hours by day, or eight hours by night, in advance of the approaching conditions, or that the dangerous atmospheric disturbances will very materially increase in force. In either case his explanatory dispatch must be so definite and clear that no misapprehension can occur. Errors of judgment should not be made more injurious to the public and this service by sending out belated warnings with the hope of saving the credit of the predicting officer in particular or this service in general.

THE INDICATIONS.

23. The indications for the succeeding twenty-four hours will be prepared by naming the states or parts of states for which each prediction is made.

24. The following statements, briefly made, are essential to the "indications": Predictions of weather; temperature; wind direction; wind force when high winds or gales are anticipated; cold waves; severe local storms and tornadoes; anticipated frosts and freezing weather as far in advance as possible; changes anticipated in the rise and fall of rivers; and, at the close, the stations, or, when the display is general, the names of lakes and sections of the sea-coast, where signals are displayed.

25. When it is possible to make the same prediction of weather, winds, and temperature apply to several states, they may be grouped together. Whenever rain is falling at one or more stations in any area, the Indications Official will so word his predictions that it is evident he has made his indications solely in the public's interest.

27. The official at Washington City will prepare indications at each report for all states east of the Rocky Mountains.

28. In the regular daily indications he will be guided in the use of terms by the interpretation put upon them in the "Instructions for Verifications."

29. When practicable, notice of expected heavy snow will be incorporated in the regular indications.

31. Since the diurnal changes in the force of the wind are so great that it is impossible to state it briefly and simply, even when known, only the direction of the wind will be predicted in making up the daily indications, except when its anticipated force will be dangerous, in which case it should be incorporated in the indications, and cautionary or storm signals will be displayed, as provided hereafter.

32. Wind signals will be ordered whenever the Indications Official considers it probable that there will occur at any of the stations men-

tioned in paragraph 34, along the Atlantic or Pacific sea-board, in the Gulf of Mexico, or on the Great Lakes, a wind-velocity dangerous to navigation, *i. e.*, reaching the velocity set opposite said station.

33. The signals ordered will indicate the degree of the intensity of the storm and the direction of the wind during the display. The degree of intensity will be indicated by two different signals, to be designated respectively the "Cautionary Signal" and the "Storm Signal," and the direction of the wind by four different signals, to be designated after the four quadrants, viz., "Northeast," "Southeast," "Northwest," and "Southwest."

34. The following are the wind directions which should occur at any station to justify the display of a direction signal: For signals for an easterly quadrant, winds from any direction from northeast to south, both inclusive. For signals for a westerly quadrant, winds from any direction from north to southwest, both inclusive.

37. In ordering signals he will hereafter set forth in the message the exact hour at which the signal shall be hoisted, and also the limit of time within which dangerous winds are expected. The hour named in the dispatch for the hoisting of the signal will not be earlier than thirty minutes after the dispatch is filed, and not later than twelve hours thereafter. The dispatch must give as exact information as is possible and cases where vessels sailing in certain quarters from ports where the signal is displayed will pass without the influence of the dangerous winds, such information will be given.

41. Twelve (12) hours on the lakes, and sixteen (16) hours elsewhere is sufficient time to hoist a signal previous to the arrival of a light storm, and the official will specify the hour at which the storm is expected to begin. In cases of severe storms for which the signal is displayed, the order may be made twenty-four (24) hours in advance on the lakes, and thirty-two (32) hours elsewhere. If a signal remains displayed for more than twenty-four (24) consecutive hours for a cautionary or twenty-four (24) hours for a storm signal, before the arrival of the verifying velocity, it will be considered a failure, except in special cases where the official announces that strong winds are expected in from twenty-four (24) to thirty-two (32) hours, when the limit given by the official will be allowed the signal. In cases where the lack of telegraphic service prevents the signal from reaching the signal station in the ordinary time, the signal will be considered as displayed at the hour set forth in the order. In cases of anticipated cyclonic storms which the official has reason to believe will arrive in thirty-two (32) or more hours, he will send out telegraphic warnings, giving the presumed centre of the cyclone and its probable line of movement, but he will add that the information in the possession of this office is insufficient to definitely locate its path or justify the definite signals.

TABLE I (Par. 34).—*Cautionary velocities (miles per hour).*

Stations.	Easterly winds with temperatures above freezing, and westerly winds with freezing temperature.	Easterly winds with freezing temperature, (NE. to S., inclusive).	Westerly winds with temperatures above freezing. (N. to SW., inclusive).
	Miles.	*Miles.*	*Miles.*
Corpus Christi	30 to 40	27 to 36	33 to 44
Galveston	27 to 35	24 to 32	30 to 38
New Orleans	24 to 32	22 to 29	26 to 35
Mobile	27 to 35	24 to 32	30 to 38
Pensacola	25 to 33	22 to 30	28 to 36
Cedar Keys	28 to 36	25 to 32	31 to 40
Key West	28 to 36	25 to 32	31 to 40
Jupiter	29 to 37	26 to 34	32 to 41
Jacksonville	27 to 35	24 to 32	30 to 38
Savannah	27 to 35	24 to 32	30 to 38
Charleston	27 to 35	24 to 32	30 to 38
Wilmington	23 to 32	21 to 29	25 to 35
Hatteras	30 to 40	27 to 36	33 to 44
Kitty Hawk	30 to 40	27 to 36	33 to 44
Cape Henry	30 to 40	27 to 36	33 to 44
Norfolk	20 to 30	18 to 27	22 to 33
Baltimore	19 to 28	17 to 25	21 to 31
Delaware Breakwater	30 to 40	27 to 36	33 to 44
Atlantic City	24 to 32	22 to 29	26 to 35
Sandy Hook	30 to 40	27 to 36	33 to 44
New York	25 to 33	22 to 30	28 to 36
New Haven	24 to 32	22 to 29	26 to 35
New London	22 to 30	20 to 27	24 to 33
Block Island	30 to 40	27 to 36	33 to 44
Wood's Holl	28 to 36	25 to 32	31 to 40
Nantucket	26 to 34	23 to 31	29 to 37
Boston	28 to 36	25 to 32	31 to 40
Portland, Me	22 to 30	20 to 27	24 to 33
Eastport	28 to 36	25 to 32	31 to 40
		All winds with temperature above freezing.	All winds with freezing temperature.
Oswego		28 to 36	25 to 32
Buffalo		30 to 40	27 to 36
Erie		28 to 36	25 to 32
Cleveland		27 to 35	24 to 32
Sandusky		30 to 40	27 to 36
Toledo		25 to 33	22 to 30
Detroit		24 to 32	22 to 29
Port Huron		30 to 40	27 to 36
Alpena		25 to 33	22 to 30
Sault Ste. Marie		20 to 28	17 to 25
Manistee		20 to 28	17 to 26
Grand Haven		30 to 40	27 to 36
Chicago		26 to 34	23 to 31
Milwaukee		30 to 40	27 to 36
Green Bay		26 to 34	23 to 31
Marquette		26 to 36	23 to 31
Duluth		24 to 32	22 to 29

TABLE II (Par. 34).—*Storm velocities (miles per hour).*

Stations.	Easterly winds with temperature above freezing, and westerly winds with freezing temperature.	Easterly winds with freezing temperature.	Westerly winds with temperature above freezing.
	Miles.	*Miles.*	*Miles.*
Corpus Christi	35 & upward	32 & upward	38 & upward
Galveston	32 "	29 "	35 "
New Orleans	29 "	26 "	32 "
Mobile	32 "	29 "	35 "
Pensacola	30 "	27 "	33 "
Cedar Keys	33 "	30 "	36 "
Key West	33 "	30 "	36 "
Jupiter	34 "	31 "	37 "
Jacksonville	32 "	29 "	35 "
Savannah	32 "	29 "	35 "
Charleston	32 "	29 "	35 "
Wilmington	29 "	26 "	33 "
Hatteras	35 "	32 "	38 "
Kitty Hawk	35 "	32 "	38 "
Cape Henry	35 "	32 "	38 "
Norfolk	27 "	24 "	30 "
Baltimore	25 "	22 "	28 "
Delaware Breakwater	35 "	32 "	38 "
Atlantic City	30 "	26 "	32 "
Sandy Hook	35 "	32 "	38 "
New York	30 "	27 "	33 "
New Haven	30 "	26 "	32 "
New London	28 "	26 "	31 "
Block Island	35 "	32 "	38 "
Wood's Holl	33 "	30 "	36 "
Nantucket	31 "	28 "	34 "
Boston	33 "	30 "	36 "
Portland, Me	28 "	25 "	31 "
Eastport	33 "	30 "	36 "

	All winds above freezing.	All winds with freezing temperature.
Oswego	33 & upward	30 & upward
Buffalo	35 "	32 "
Erie	33 "	30 "
Cleveland	32 "	29 "
Sandusky	35 "	32 "
Toledo	30 "	27 "
Detroit	30 "	27 "
Port Huron	35 "	32 "
Alpena	30 "	27 "
Sault Ste. Marie	25 "	22 "
Manistee	25 "	22 "
Grand Haven	35 "	32 "
Chicago	31 "	28 "
Milwaukee	35 "	32 "
Green Bay	31 "	28 "
Marquette	31 "	28 "
Duluth	30 "	27 "

42. A signal is intended to remain displayed twenty-four (24) hours from the hour at which it is ordered, unless the Indications Official should deem it proper to order "signals down" before the expiration of the twenty-four (24) hours in question, or should order it for thirty-two (32) hours. Either in the orginal order or in the case of continuance, the Indications Official has the discretion to specify the time at which the signal shall be lowered, but in all cases where such time is not explicitly named, it is to be understood that the signal shall remain displayed for twenty-four (24) hours, and that each continuing signal shall likewise be displayed twenty-four (24) hours longer. (In case the time of expected high winds is not given in the dispatch and the signal displayed is not justified within sixteen (16) hours after its original order, or sixteen (16) hours after the continuance thereof, on the lakes, but is justified within the last four hours of the display, it will be given only the same value as a late signal.) Observers are instructed not to lower a signal at any time unless the velocity of the wind for one hour previously has been at least four miles below the minimum velocity required to justify the signal.

52. Signals will be ordered for Baltimore, Maryland, whenever a storm is anticipated on the Delaware, Maryland, or Virginia coasts. They will be considered justified if the wind reaches the verifying velocity at at any station within that section.

56. The time and date at which a storm is expected to arrive at the districts or stations threatened will be given in the words, morning or night of ——— (day of month).

61. *Severe local storms and tornadoes.*—The Indications Official will give special attention to conditions favorable to the development of severe local storms and tornadoes. When the reports justify the prediction of these storms they will form a part of the general indications, the prediction to be, that — "conditions are favorable for the occurrence of severe local storms or tornadoes," giving the names of the states where such storms are expected to occur.

62. Whenever severe local storms are predicted, as provided for above, the Indications Official will telegraph the prediction as a special message to all Signal Service stations within the threatened districts, and to the Directors of the State Weather Services of Minnesota, Ohio and Alabama, whenever the warning affects the respective states. Indications Officials will use great care in sending out warnings of severe storms and at the end of their tours will make written report of warnings sent and the results thereof, so far as can be learned.

69. Telegraphic warnings will be sent to all stations within the districts menaced by dangerous floods; when floods are likely to occur in regions where there are no stations, a warning will be sent to the signal

Station nearest to the threatened locality, with directions to give the widest publication.

73. *Frosts.*—Officials will carefully study the meteorological conditions preceding damaging frosts. Such as threaten any crop or fruit will be annonnced in indications and by special telegraphic bulletins as early as practicable, and if possible, one or two days in advance. These frost warnings will define the regions threatened, state the time and distinguish between light frosts, killing frosts, and *freezing* weather. They will be sent, as the case demands, to parties named in the schedules on file. The official in charge may call upon the other officials skilled in indications for their opinions as to the minimum temperature to be expected and the area threatened.

74. When frosts which may prove injurious to crops are likely to occur, the special bulletin will contain special warnings of their approach, which the official in charge of indications will telegraph to the observers at stations in the threatened districts; with directions to give them the widest distribution.

75. Whenever minimum temperatures of 40° or less, with conditions favorable for frosts, are expected, warnings will be telegraphed to the centres named in the several schedules filed in the Indications and Telegraph Divisions, as follows: for the fruit growing regions, from November 15 to April 15; for the tobacco growing regions, from September 1 to November 1, or until after killing frosts: for the sugar-growing regions, from October 1 to April 1, or until after killing frosts; for the fruit and vegetable districts, about Chattanooga, Tennessee, from September 15 to May 1: for districts about Georgetown, South Carolina, from October 1 to April 1; for the cranberry districts from May 1 to November 1.

76. The frost warnings for the sugar-growing regions of Louisiana will be telegraphed to the Signal Service observer at New Orleans, who will promptly furnish copies to associations interested. The official in charge of indications will exercise great care in preparing these warnings and make them descriptive of the conditions expected to occur in the northern and southern parts of the state; he will also give the time at which the cold wave or frost will probably reach the state. Warnings will not be given unless light frosts are expected at least in the northern section of the sugar-growing region; and when the temperature will probably fall below, or to, freezing in *any* section of the sugar-growing region, it will be so stated.

77. Special frost warnings for the cranberry-growing regions of Wisconsin will be prepared and telegraphed to the observer at Milwaukee, who will distribute them, by telegraph, to selected points in the counties of Jackson, Monroe, Juneau, Adams, Waushara, Marquette, Green Lake and Wood.

78. The warnings for all cranberry districts will cover a period of twenty-four hours, and, if possible, thirty-six hours in advance; the warning to always terminate at 8 A. M. If the frosts are expected to continue beyond that period, a new warning will be telegraphed. In preparing the warnings, the time at which the frost is expected to reach the cranberry-growing districts will be given.

79. As the most successful protection against frost, and the one generally employed by growers, is to cover the marshes with several inches of water and keep the same in motion, and as this precaution involves considerable expense and loss of time during the picking season, it will be necessary to use great caution in making frost predictions for the benefit of this industry.

80. The picking season begins about September 1 and lasts about six weeks. This is a period of great danger, as the least frost ruins the fruit.

84. *Freezing temperatures in canal regions.*—During the period of navigation when freezing temperatures are anticipated in any canal region, special forecasts will be made in the indications and special bulletin.

85. *Cold Waves.*—During his tour of duty, the official in charge of the Indications Division will make a study of approaching changes of temperature as indicated in the Northwest, Montana, Manitoba and Dakota, and adjacent sections with a view of determining rules of value in predicting cold waves. A careful study of the charts on file for past years will probably indicate practical rules of great value.

87. Cold-wave warnings will be usually for a period of 24 hours, but they may be displayed in the case of very pronounced types 36, or more, hours in advance. When the period covered by a cold-wave signal order is other than 24 hours from 8 A. M. or 8 P. M. (as the case may be), such variation from the usual time must appear in the original record of cold-waves, and the signal will commence at such time, between the hours of sunrise and sunset, as the official may direct. When a cold-wave signal is ordered and justified, and a severe cold-wave occurs wholly within the 12 hours following the observation on which the signal was based, such cold-wave signal will be regarded as late, and will be credited with 75 per cent. only of success. All cold-wave signals followed during the display by a fall in temperature to within one degree of the limits assigned for full verification will be considered partly verified and will be given a weight of 75 per cent. Any continuance of a cold-wave signal will be considered as a new signal, but when the original signal has been fully verified the continuing signal may be verified by a fall of 12 degrees. During the autumn months, until a killing frost shall have occurred, the fact of a frost or a killing frost at or near any station being reported will be equivalent to a record of 32 degrees.

90. Cold-wave signals will not be ordered unless a temperature of 45°, or less, is expected. When the temperature is expected to fall 20°, or more, in any district, and not reach 45°, the official in charge of the Indications Division will announce such change in a "Special Bulletin" and in the indications. No signals will be displayed for such changes.

98. During the hurricane season he will add to the messages sent to stations in the south Atlantic and Gulf states notifications of cyclones and their movements, the messages to be limited as nearly as practicable to twenty words, so as to avoid any additional cost.

INSTRUCTIONS FOR VERIFICATIONS.

164. The daily predictions made from the 8 P. M. report will be verified, respectively, by state areas for weather and temperature. The verifications will not be determined until ten days after the date on which the indications are made, unless the data from all stations affecting the verifications have been entered on the charts.

165. The official in charge of verifications will draw green lines inclosing areas reporting rainfall. These lines will pass very near stations reporting "traces," and will have such relations to stations reporting measurable amounts as accord with their character as lines of little or no rainfall. The official drawing these lines will be guided by the principle that rainfall at a station will, in general, imply that rain has fallen over half the area between this and adjacent stations; so that, for example, if rain is reported at Boston and fair weather at Albany, then, so far as these two stations are concerned, the rain line should pass midway between them. However, if, on the one hand, the amount of rainfall reported is only a "trace," or a few hundredths of an inch, or there is evidence otherwise of only a light or local rain, or, on the other hand, there is evidence of a general rain, then the line will be located so as to inclose a smaller or larger area, as the case may require, and to represent, in the judgment of the official, the most probable limits of the actual rain region.

166. In determining the percentage of verifications of predictions, the conditions occurring during the twenty-four hours predicted for, as shown by the charts for the 1st and 2d reports following the report on which the prediction is made, will be carefully examined by the verifying officer, who will ascertain the extent, on a scale of ten, to which the conditions predicted have prevailed in the states or territories, or parts of states or territories.

167. Equal weights will be given to the two maps which are used in verifying the indications.

168. Weather: All predictions of weather will be verified by consulting Chart I, Weather, of the Indications Division; reference being had on the respective maps of this chart to the green lines inclosing areas of rainfall.

169. Fair Weather: A prediction of fair weather will be construed to indicate the absence of rainfall, and will be verified by consulting the two maps separately. Any portion of the rain region extending within the district for which the prediction is made, will reduce the percentage according to the amount of district area affected.

170. Rain or snow, general rain, etc.: Such predictions will indicate that precipitation (rain or snow) will occur throughout the district during a considerable portion of the time for which the prediction is made, and any prediction of rain will be considered fully verified when from 60 to 80 per cent. of the district is within the rain region during the twenty-four hours; the percentage allowed will vary according to the size of the district and the number of stations therein.

171. "Local showers," "local rain or snow," "occasional light rain," etc., are terms to be discouraged, and are to be only used when such predictions are plainly in the public's interest. In verifying them the predictions will be considered as indicating both fair weather and rain in the district, and a weight of 50 will be given to each prediction.

172. Rain or local rain, followed by fair; fair weather, followed by rain or local rain, etc.: Such predictions may be made, and will be considered verified when the conditions predicted prevail throughout the district in the order named. When the expressions evening or night are used in double predictions, the conditions to which these terms apply will be expected to prevail before 8 P. M. for evening, and after 8 P. M. for night.

173. The prediction clearing weather "Friday," "Thursday afternoon," etc., may be made when either general or local precipitation prevails. The verification will be determined from the second map following the map upon which the prediction is made. "Fair" must prevail throughout the district at the time of the observation, and in case the expression after noon has been used rain will also be required over from 60 to 80 per cent. of the district.

174. Temperature: All expressions relating to temperature changes will be considered to refer to changes in twenty-four hours. All predictions of temperature, except predictions of cold waves, will be verified by consulting Chart III (Temperature Changes) of the Indications Division; reference being had on the respective maps of this chart to the red line of zero change of temperature in twenty-four hours.

175. Warmer, higher temperature: Predictions of warmer weather, higher temperature, etc., will indicate that the temperature at the second observation after the observation on which the prediction is made will be higher than the temperature at the observation twenty-four hours preceding. Such predictions will be verified by consulting the maps for the second reports following the report on which the prediction is made, and will be considered as perfectly verified when the entire district, as

shown on both maps, is on the plus or warmer side of the red line of zero change of temperature in twenty-four hours. Any portion of the district that may be on the colder or minus side of this line, on either map, will lower the percentage according to its area.

176. Colder, lower temperature, etc.: Predictions of colder weather, lower temperature, etc., will indicate that the temperature at the second observation after the observation on which the prediction is made will be lower than the temperature at the observation twenty-four (24) hours preceding. Such predictions will be perfectly verified when the entire district, as shown on the second map, is on the colder or minus side of the red line of zero change of temperature in twenty-four (24) hours.

177. Colder followed by warmer; warmer followed by colder, etc.: Such predictions will indicate that the temperatures at the first and second observations following the observation on which the prediction is made, will be lower and higher, or higher and lower, respectively, as the case may be, than the temperatures at the observations twenty-four hours previous, each to each. They will be perfectly verified when the temperature changes throughout the district, as shown on the first and second maps following the map from which the prediction is made, have been in accordance with the prediction.

178. Stationary temperature: The term stationary temperature indicates a change of three degrees or less from June to September, inclusive; five degrees from November to February, inclusive, and four degrees for the remaining months. Predictions of stationary temperature will be verified by consulting the second map following the map from which the prediction is made.

179. Winds: The verification of predictions of wind will be confined to the verification of the display of cautionary and storm signals.

180. Justification of wind signals: The justification of wind signals will be determined by districts. All signals (one or more) displayed in one district at the same time counting as one signal. The following are the districts established:

District.	Includes.
West Lake Superior	Duluth, Minn., to Ontonagon, Mich., both included.
East Lake Superior	East of Ontonagon to Sault Ste. Marie, Mich., included.
North Lake Michigan	All stations on Lake Michigan from lat. 44° N. northward to and including Mackinaw City.
South Lake Michigan	All stations on Lake Michigan from lat. 44° N. southward.
Lake Huron	All stations on Lake Huron, Mackinaw City excluded.

Lake Erie.....All stations on Lake Erie, including Detroit.
Lake Ontario.....All stations on Lake Ontario.
East New England coast.....All stations from Eastport included to Chatham, Mass., excluded.
South New England coast.....All stations from Chatham, Mass., to New York City, both included.
New Jersey coast.....All stations from New York City to Cape Henlopen, both included.
Cape Henry.....All stations from Cape Henlopen excluded, to Hatteras, included.
Carolina coast.....All stations from Hatteras excluded, to Charleston, included.
East Florida.....All stations from Charleston, excluded, to Point Jupiter, included.
Key West.....All stations on Florida Keys.
East Gulf coast.....All stations from Punta Rassa to Appalachicola, both included.
Central Gulf coast.....All stations from Appalachicola to Sabine City, both excluded.
West Gulf coast.....All stations from Sabine City, Tex., to Brownsville, Tex., both included.

181. A signal will be recorded as justified for velocity if the wind during the display attains a justifying velocity as prescribed by Tables I and II, paragraph 84, at one or more stations in the district. The Indications Official may submit in writing to the Chief Signal Officer evidence of the justification of signals; such as the occurrence of severe gales, marine disasters from stress of weather, etc., in the vicinity of stations where signals were displayed.

182. Signals will be considered as verified for direction by the following winds occurring during the display at one-half or more of the stations in the district; signals for an easterly quadrant, by winds from any direction from northeast to south, both inclusive; signals for a westerly quadrant, by winds from any direction from north to southwest, both inclusive. If a signal be changed from an easterly io a westerly quadrant, or from a cautionary to a storm, or *vice versa*, the new signal will be treated as a separate signal, both as to direction and velocity.

183. When cautionary signals are ordered and storm winds occur, or *vice versa*, at more than one-half the stations in the district, the signal order will be considered as verified for velocity to the extent of 75 per cent.

184. When signals are ordered for a station and never received, as when telegraphic communication is interrupted, such signal will for pur-

poses of verification be considered as displayed at the time specified in the order.

185. A cautionary signal changed to a storm signal may be justified by a justifying velocity occurring after the change, if within twenty-four hours (24) after ordered, but a storm signal will only be fully justified by a storm justifying velocity occurring during the display.

186. When signals are ordered for a station and the wind at the time of the report is blowing at the rate of the verifying velocity, but falls below that velocity before the signal is ordered, such signal will be considered as not verified, but the wind will not be counted as a wind for which signals were not ordered; if, however, the verifying velocity continues after the signal is ordered the signal will be considered as late, but verified.

187. A storm without signals will be recorded whenever a justifying velocity without signals steadily obtains for one hour or more at one station, or for half an hour or more during the same 12 hours at two or more stations of the same or contiguous districts.

188. Only one such storm without signals will be reported in any period of twenty-four consecutive hours, from the same district, the period to begin at the observation immediately preceding the first occurrence of the justifying velocity.

189. The percentage of justification of wind signals will be determined as follows:

The total number of signals perfectly verified during the month will be multiplied by one hundred. The total number of signals ordered late, plus those ordered as cautionary when storm signals should have been displayed, or *vice versa*, and those verified in accordance with the provisions of paragraph 42, if verified both as to velocity and direction, will be multiplied by seventy-five, if as to velocity only, by forty-five. The total number of other signals verified for velocity *only* will be multiplied by sixty. The total number of signals verified as to direction only will be multiplied by forty. The sum of all these products will be divided by the total number of signals ordered, plus one-half the total number of storms without signals. The quotient will be the monthly percentage of verifications of the display of cautionary and storm signals.

190. A cold wave will indicate that the temperature will fall fifteen (15) degrees, or more, in twenty-four (24) hours, or less, after the diurnal change has been eliminated, and to forty-five (45) degrees or below. The prediction will be considered verified when such a change is reported from two or more adjacent stations, not less than 100 miles apart.

191. The percentages of verifications of predictions of cold waves will be determined as follows:

The total number of signals perfectly verified during the month, deducting signals ordered late, will be multiplied by one hundred (100); the total number of signals ordered late, plus the total number partly verified, will be multiplied by seventy-five (75); and the sum of these products will be divided by the total number of cold wave signals ordered, plus one-half (½) the number of severe cold waves without signals. The quotient will be the monthly percentage of verifications of predictions of cold waves.

A severe cold wave will be one in which the temperature has fallen abnormally 20° or more at adjacent stations in twenty-four hours or less, and to 40° or below.

192. The monthly percentages of verifications of predictions of weather and temperature for each state and territory will be combined by multiplying the respective percentages of verifications of predictions of weather by six (6), and of temperature by four (4), and dividing the sum of the respective products by ten (10). The quotient will be the average percentage of verifications of predictions of weather and temperature for the particular state or territory and month in question.

193. The general monthly percentage of verifications of all indications will be determined by multiplying the general monthly percentage of verifications of weather and temperature combined by five (5); of the display of cautionary and storm signals by two (2); of cold waves by one (1); and dividing the sum of the products by eight (8); except during those months in which not more than three cold-wave signals are ordered, when cold waves will be omitted and the sum of the remaining products will be divided by seven (7). The quotient will be the general monthly percentage of verification of all indications.

CORRESPONDENCE.

THUNDER IN OREGON.

To the Editors:—As thunder is rare, and by some said not to occur in Oregon, it may be noted for record, that at 11:53 A. M., standard time, to-day, peals of thunder and the characteristic rolls and reverberations were heard to the eastward from this place, which is near Salem in the Willamette valley. There was evidently a marked "low"; it had rained heavily in the morning, after 24 hours southerly wind, and had partially cleared. The sun shone very warm and a thunder-cloud, such as is common in Michigan summers, passed across the eastern sky from south to north.

Yours truly, W. H. H. Beadle.

Chemawa, Oregon, April 22, 1889.

COMPANION METEORS.

To the Editors:—In the year 1838 when a small boy only nine years old I saw what I now know were two falling aerolites. As 51 years have elapsed since that time I can not remember the exact day or even month, but only that it was sometime during the summer or early autumn of the year above named. It would seem strange if others did not see the same, yet I have no recollection of hearing them spoken of by others, nor of myself at the time telling any one what I saw. My parents were then living in the northwestern part of Monroe county, N. Y.; to be exact, about 1½ miles east of the west line of the county and about the same distance south of the lake. Early in the evening, sometime between sundown and dark, I was alone in the yard on the south side of the house, when suddenly I heard a humming or whizzing noise as of some solid body moving with great velocity through the air. Quickly looking up in the direction from which the sound came I saw directly south of me and at an elevation of about 45 degrees two meteors, the larger one ahead and the smaller following directly in the larger one's path and so close that they apparently touched each other. Their apparent distance from me was about 125 or 150 feet, but I have no doubt their real distance was very much greater. They were, however, so near that I could clearly see they were solid bodies and could plainly hear the humming noise (it sounded much like, and about as loud as, the droning of a large bee) that they made in rushing through the atmosphere. They were moving with great velocity in a direction a very little north of west. In a very few seconds they had passed out of my sight. In regard to their magnitude, it is almost impossible to form any idea of even the apparent magnitude of a body at a considerable, but entirely unknown, distance, and at the same time moving with great velocity. But perhaps I can convey to the reader some idea of how large the meteors looked to me by saying that had they passed directly between my eye and the full moon, I think their entire length would have extended across the moon's disc. They were shaped alike and each was about one-third as thick

as it was long. They were at, or nearly at, a white heat, and from the front end of the larger one sparks of fire were thickly flying that resembled the sparks from a large piece of iron heated to a welding heat. Fifty-one years have elapsed since that time and I have written from memory, but have been very careful to state nothing but what I distinctly remember.

WARREN HOPKINS.

ALGONAC, MICH., April 23, 1889.

CURRENT NOTES.

THE annual meeting of the American Climatological Society will be held in Boston, June 24th and 25th. Dr. V. L. Bowditch, of Boston, President.

OUR COMPETITION FOR STUDIES OF TORNADOES.—As we have begun to receive essays intended for this competition, we would announce that the subscriptions, which are to be returned for the deposit required, will, in all cases, begin with the July number, unless otherwise requested. The deposits should be sent to one of the editors. If they are sent in to the manager they will be credited on his books, which are open to inspection, and we cannot then guarantee entire secrecy as to the name of such contestant. No acknowledgment of the receipt of the essays will be made unless specially desired. It would be well to send them by registered or special delivery mail, or by express.

INTERNATIONAL CONGRESS.—The second session of the Hydrological and Climatological International Congress will be held at the Paris Universal Exhibition from October 3rd to 10th inclusive.

Members are to be charged twenty francs to defray the expense of a full report of the proceedings.

Delegates will have free admission to the Exhibition when the Congress meets in the building.

There will be three sections: (1) Hydropathic; (2) Scientific and Medical; (3) Climatological.

M. E. Renou, director of the St. Maur Meteorological Observatory and Vice-President of the Meteorological Society of France, has been chosen as President of the Congress by the committee on organization. Dr. Daujoy, President of the Medical Hydrological Society of Paris, is Vice-President of this committee, and Dr. F. de Rauce is Secretary-General. The latter will supply information to correspondents addressing him at 53 avenue Montaigne, Paris, France.

PREDICTIONS FOR TWO OR THREE DAYS.—From a press dispatch of April 29, we learn that the Chief Signal Officer has issued the following instructions to the Indications Official: In view of the great importance of long-time weather predictions to the business interests of the country, it is hereby directed that on and after May 1, 1889, the Indications Official shall make, whenever practicable, a general prediction, showing the condition of the weather two or three days in advance. This class of long-time predictions will be confined to such occasions and such sections of the country as from peculiar and persistent meteorological conditions seem to urge successful forecasts.

These predictions will not be too much in detail, but will clearly set forth the section of country for which they are intended and the days of the week which they will cover. The use of such terms as "warmer," or "colder" should be replaced as a rule, by "warm," "cold," "moderately cold," etc. In making these long-time forecasts, the language should be varied according to the necessities of the occasion, but should always be in such form as to convey clearly to the general public the opinions of the Indications Official and also the degree of positiveness that attaches to his opinions.

METEOROLOGY IN THE NAVY.—The Division of Marine Meteorology, U. S. Hydrographic Office, has been in charge of Ensign Everett Hayden, U. S. N. (retired), for the past two years, and the readers of this JOURNAL have no doubt watched with interest the efforts that have been made, with the small force and limited means at command, to do justice to the im-

portant work intrusted to it, and to maintain the reputation of the monthly *Pilot Chart* of the North Atlantic Ocean, published under its supervision. Lieut. H. M. Witzel, U. S. N., who has only recently returned from a three years' cruise in the Pacific on the U. S. S. Vandalia, has been detailed to take charge of this important division of the Hydrographic Office, entering upon his new duties May 10th. It is only fair to say that this detail was made at Mr. Hayden's express request, and this addition to the working force of the division must result in its increased efficiency and success. Mr. Witzel graduated with great distinction in the class of '77 at the Naval Academy, and his natural tastes and professional training and experience render his selection peculiarly gratifying to all those who wish to see our Navy department take an advanced position in the prosecution of every branch of our meteorology. This vast field will well repay the most careful study of our brightest officers, and the fact that such work is not only interesting and instructive to those engaged in it but vitally important to the Navy in general (which depends upon the Hydrographic Office for the latest and best information in every branch of Hydrography and Meteorology), leads us to hope that the Navy Department will make every effort to regain the prestige it had when Maury enlisted the support of navigators of every nationality in his great scheme of marine meteorological research.

AN ATTRACTIVE STAR-ATLAS.*—This is a very attractive atlas, convenient in size, its accuracy guaranteed by the known competency of its author. It is the best suited of any we know for the use of amateurs with small instruments, and it is especially adapted to the needs of the comet-hunter. Twelve of the maps are devoted to a review of the constellations, and in these all names and reference symbols are in red, while the stars are in

*Star-Atlas, containing Maps of all Stars from 1 to 6.5 magnitude between the North Pole and 34° South Declination and of all Nebulæ and Star-Clusters in the same region which are visible in telescopes of moderate powers, with explanatory text by Dr. Hermann J. Klein. Translated and adapted for English readers by Edmund McClure, M. A., etc. Eighteen charts and 81 pages of illustrative letterpress. Imperial 4to, cloth. London: Society for Promoting Christian Knowledge. New York: E. & J. B. Young & Co.

black and the usual figures of the constellations are omitted. In this way much of the confusion of the ordinary star-maps is avoided. The remaining six maps are devoted to reproductions of the best drawings and maps of the most interesting nebulæ and clusters. The text is made with reference to the wants of amateurs, and contains a long list of the most interesting bodies visible in small telescopes, with detailed descriptions. Altogether it will form an almost indispensable addition to the library of those possessing small telescopes, and it will doubtless be found useful, on account of its handy form and size, to professional astronomers having access to other and more pretentious atlases. It also commends itself by its very moderate price.

A GERMAN CLOUDBURST.—Dr. Hellmann has published in the *Centralblatt der Bauverwaltung*, a brief study of a cloudburst, August 2d and 3d, 1888, in the Riesengebirge, in Silesia. The storm was on the west side of a storm area, which was moving northward from Galicia. The rain fell from 15 to 18 hours, and in some parts of the Queiss valley its depth reached 200 mm. or 7.9 inches. Such a rain-fall had not been known there before since 1804. A similar cloudburst occurred in the region just southeast of this, in the Sudeten and Beskiden mountains, in 1884, accompanied a similar unusual progression of a storm area northward over Galicia and Polen.

WHIRLWINDS, WATERSPOUTS AND TORNADOES.—These phenomena, it should be remembered, are of the same general character, and it has been found that, whenever they occur it is in connection with a general cyclonic storm of large area. The principles involved in their formation are almost identical with those that determine the formation of a tropical cyclone, that is, great contrasts of temperature and moisture between adjacent layers of air. In the United States and off our coasts they may therefore naturally be expected to occur to the southward of a storm center, where cold, dry northerly winds blow over and mingle with warm, moist air from the southward. That they may occur to the north of a storm center, however, under certain conditions,

is indicated by a report from Second Officer Madge, of the Br. S. S.. "Lake Winnipeg," Captain Murray. This vessel encountered a severe cyclonic storm February 27, lat. 40° 50′ N., long. 56° 48′ W., and at 2:30 P. M., when it was blowing a strong gale from the east, a whirlwind was observed moving due west. The barometer was low, and the warm, moist east wind was evidently underrunning a cold, dry current of air from the area of high barometer to the northward, where readings of 30.4 inches and upward are reported. It will thus be seen that local conditions of pressure, temperature and moisture may cause exceptions to the general rule.—*Pilot Chart.*

FORM AND POSITION OF SEA LEVEL.*—If any of our readers wish to solve a problem relating to changes in level of a water surface due to the disturbing attraction of bodies near enough to affect them, they will have the means in this pamphlet. Several simplifications must be assumed, and they can be usually assumed safely in any practical case in hand. The mathematics by which the formulas are obtained, is by no means of an elementary character, and Mr. Woodward deserves much credit for the way in which he has handled them, and for the practicable form to which he has reduced them. Not nearly so good a knowledge of mathematics is required for the use of the formulas, and the author has rendered their use possible to one who has not taken the time to read the whole treatise.

THE BATAVIA (JAVA) OBSERVATORY.—The volume for 1887, on the Rainfall in the East Indian Archipelago, is the ninth of the series. It contains the rainfall data, day by day, for 184 stations, of which 102 are on Java and Madœra, 40 on Sumatra and adjacent islands, while 42 are scattered over other parts of the archipelago. The final tables in the book give monthly or annual means for five or more years, also the mean number of days on which rain fell. The largest annual rainfall noted was

* Department of the Interior, Bulletin of the U. S. Geological Survey, No. 48. On the Form and Position of Sea Level, with special reference to its dependence on superficial masses systematically disposed about a normal to the earth's surface. By Robert Simpson Woodward. Washington, 1888. Octavo, 86 pages.

4561 mm., at Padang. The greatest number of rainy days was 248 per year at Padang-Pandjang. Padang is on the west coast of Sumatra, and Padang-Pandjang is a score or more of miles to the north of the former, and at an elevation of 780 m.

The rainfall volumes are in octavo, the observations are in large quarto. The latest of the latter which have appeared are Vols. VIII and X. The former contains hourly observations at Batavia, and their results for 1883, 1884 and 1885. The latter contains the same for 1887, and also the magnetical observations and results for the same year. It also contains two appendices, —one on the solar and lunar diurnal variation of the magnetic elements, the other on the period of rotation of the sun as determined by meteorological data. The tropical position of Batavia permits an easy determination of periodic changes in the meteorological elements, because the non-periodic changes are there very few. An examination of the changes of the barometer leads Dr. Van der Stok to the detection of a 26-day period, or, more exactly, of 25.81 days; a period agreeing remarkably with the period of the sun's rotation. The magnetic period determined at Batavia was 25.86 days.

CLIMATOLOGY OF NEW JERSEY.*—In the space of nearly one hundred octavo pages, Professor J. C. Smock discusses the climate of the small state of New Jersey. The data employed are not very numerous, but include, in long series or short, 90 different stations. The State is divided into four climatic areas, the Highlands, the north interior, the south interior, and the coast area. The first is in the northwest corner, the last along the Atlantic coast. The south interior is on the whole the warmest, preceding the Highlands by about a month in the spring and following by nearly as much in the autumn. The coast area fringes the Atlantic and is but a few miles wide. Professor Smock gives *in extenso* the annual and monthly means of the meteorological elements for all the stations. In addition to the information which must be given in such a report, Professor Smock

* Climatology of New Jersey, by John C. Smock. From the Final Report of the State Geologist. Vol. I, pp. 325-421, Trenton, 1888.

adds supplementary information of an interesting character and suitable for reference. Such are the chronological notes beginning with 1607 and ending with the March blizzard of 1888; also the table of the opening and closing of the Hudson river at Albany since 1646, of the closing of navigation on the Delaware river at Philadelphia since 1872, the dates of opening and closing of navigation on the Delaware and Raritan canal since 1834, and similarly for the Morris canal since 1869. Many other tables are scattered through the report, and the whole forms a valuable addition to the meteorologist's library.

OBSERVATIONS MADE AT THE BLUE HILL METEOROLOGICAL OBSERVATORY IN THE YEAR 1887. A. Lawrence Rotch, Director. —A new departure is made in the publication of Mr. Rotch's annual volume, the present one appearing as Vol. XX, Part I, of the Annals of the Harvard College Observatory, Edward C. Pickering, Director. In the preface, Professor Pickering states that the Directors of the above mentioned institutions have entered into an arrangement by which this new form of publication will be continued from year to year, "and the ultimate consolidation of the two institutions is contemplated."

The present volume will make all American meteorologists feel proud that such a model of completeness of meteorological data and beauty of press work is to be distributed the world over among meteorologists and observatories.

Mr. Rotch was the first to remove the standing criticism of European meteorologists that no records of self-registering instruments were being published for the whole United States, notwithstanding the fact that a million dollars a year is being spent by our government for meteorological purposes.

In the equipment of his observatory and in the form of publication of results, and most probably in the methods of reduction of self-recorded data, Mr. Rotch has made a wise use of his extensive studies of the foreign observatories; and the new arrangement by which the computing force of the Harvard Observatory will assist in calculating will insure a more complete working up of the observations than has heretofore been done.

It is an established rule that the whole time of at least three persons is necessary for the carrying on of a meteorological observatory of the first rank; and the considerable expense that must be met in the way of salaries will prevent the rapid increase in the number of such observatories, as the "Blue Hill," in other parts of the country, unless U. S. government or state aid is given.

The present volume contains a brief description of the apparatus at the observatory; monthly means and totals; monthly extremes; days of visibility of western mountains; hourly values of atmospheric pressure; annual summary of hourly pressures; hourly air temperatures; annual summary of hourly air temperatures; number of hours of prevalence of each wind direction; hourly wind azimuths and movements; number of times the wind blew from each 10° of azimuth; annual summary of hourly wind movements; hourly precipitation; annual summary of hourly precipitation; hourly bright sunshine; annual summary of hourly sunshine; cloud observations; hourly cloud observations (7 A. M. to 11 P. M.); annual summary of hourly amount of cloud (7 A. M. to 11 P. M.). Appendices: Comparisons of thermometer shelters; investigation of the normal differences of temperature between the base and summit; investigation of the marked inversions of temperature between the base and summit; tracings from the self-recording instruments illustrating certain meteorological phenomena.

The most important of these observations (because the rarest for American stations) are the hourly rainfall, the hourly sunshine, and the hourly cloud observations. These last are especially valuable, and their promised forthcoming discussion will be looked for with much expectancy; and it is hoped that the enthusiasm which alone could have sustained the observers in performing such an arduous and confining task (where so few observers take part) will be well rewarded by their obtaining important results from the discussion of the observations.

The appendices contain matter of much interest in connection with the subject of change of temperature with elevation—of the greater interest because the differences in elevation are only

a few hundred feet and near the sea coast, while those usually investigated are for greater elevations and inland.

The columns of this JOURNAL will probably contain many references to this important contribution of Director Rotch and his assistants; for all such American data should be worked up and used in our theoretical studies in place of the European data now necessarily almost exclusively used.

FRANK WALDO.

ESPY ON THE LOW PRESSURE AT THE POLES.—In the synopsis of his theories that Espy prefaces to his "Philosophy of Storms" (1841), there is a close approach to a discovery of the cause of the low pressure about the poles that has been so great a difficulty in the text-books until a simple solution of it was proposed by Ferrel. Espy wrote: "The effect of the air rolling off from above the equator toward the poles, when considered alone, would cause the barometer at the very poles to stand above the mean; but the centrifugal force of the air in the frigid zone, arising from the diurnal revolution of the earth on her axis, produces a countervailing force of considerable power, and flattens the atmosphere at the poles more than the earth is flattened, because it is of greater diameter, and perhaps this may cause the barometer to stand below the mean very near the poles." The conclusion is wrong, for an atmosphere in equilibrium under diurnal rotation would exert uniform pressure all over the world, and the centrifugal force cannot be called on to reduce the polar high pressure that is caused by low temperature. But if Espy had only mentioned the excess of eastward velocity that the greater mass of the atmosphere possesses compared to the earth, he would have solved the problem; and it is curious that he omitted this, for he spoke of it explicitly in an earlier paper in 1833 (Journal Franklin Inst., xii, 1833, 293). The whole of the synopsis is excellent reading for the modern meteorologist.

W. M. D.

THE FORESTRY DIVISION OF THE DEPARTMENT OF AGRICULTURE.—The great activity and zeal of Mr. B. E. Fernow, who has now been for three years at the head of the forestry division,

has resulted in attracting the public interest strongly to the condition of our forests and to the necessity of our preserving and enlarging the forest area. The relations between forests and meteorology are intimate, and in Mr. Fernow's publications there is much which will interest meteorologists. In the annual report for 1887, Mr. Fernow calls attention to the desirability of phenological observations. On pages 68 to 70 he gives instructions and cautions to observers, by regarding which they can arrive at the best results. Phenological observations have been, not exactly neglected, but only sporadically carried on in the states. Mr. Fernow desires the hearty support of botanists and meteorologists, in making such observations systematic. If he would select a good list of well-known and easily identified species of plants, appeal to the large public interested in such work and capable of doing it, and ask them to make observations on these particular species, we have no doubt he could collect, in a few years, a great mass of valuable information. In the meantime, some one should explore the large number of observations already made; doubtless interesting conclusions could be safely drawn from them.

Mr. Fernow also makes the suggestion (page 70) that the agricultural experiment stations and colleges should make regular observations of forest climatic conditions, and indicates the observations and instruments required and the expense involved.

Bulletin No. 1 of the Division was published in 1887, and is a report on the relation of railroads to forest supplies and forestry. It attracted much popular attention at the time it was published, and the discussion of forest fires given in it will interest meteorologists.

Bulletin No. 2 was published in 1888, and is a report on the forest conditions of the Rocky Mountains. It contains papers by various individuals on the government in its relation to forests, the legislation for the preservation of timber or forests proposed or passed, before or in 1888, forest conditions of the Rocky Mountains, with a map showing the location of forests and the principal irrigating ditches in this region, forests of southern California, needs of the Yellowstone National Park,

and the flora of the Rocky Mountains and of San Diego county, California.

There are, besides, two papers of more direct interest to our readers. The first is by George H. Parsons, and relates to the climate of Colorado and its effects upon trees. The sketch of the climate is brief, and Mr. Parsons finds that the great range of temperature, the warmth of the sun's rays in cold weather (due to the elevation of the State), the low humidity, small rainfall, rapid evaporation, small cloudiness, and the "northers" and "Chinooks" are all unfavorable to tree growth. A note of interest, which we do not remember to have seen before, is that irrigation can only partially supply the tree with the moisture it needs, and can never give it the rich, luxuriant foliage which it may have in moist climates.

The other paper to which we especially refer, is that of Mr. Fernow on snow-slides and avalanches,– their formation and prevention. The author finds no American literature on the subject, but draws on the volume of the Swiss Forest Inspector, Coaz. There is, of course, a large newspaper literature on the subject in this country. The phenomena occur on a magnificent scale in the west, and it is the lack only of scientific observers which has prevented their scientific study. Mr. Fernow's paper is only the introduction to what will probably rapidly become a large and important literature.

THE LADY FRANKLIN BAY EXPEDITION.*—This is the official report of the Lady Franklin Bay Expedition. The first volume contains the report of the officer in command, and appendices which include detailed reports of special expeditions and the diaries of two members of the party— those of Lieutenant Lockwood and Sergeant Brainard. Both volumes contain many maps, diagrams, and illustrations, the latter often copies of photographs taken on the spot. The entire first volume can be looked on as a sort of diary of the expedition. It contains very

* International Polar Expedition. Report of the Proceedings of the United States Expedition to Lady Franklin Bay, Grinnell Land. By First Lieutenant A. W. Greely, Commander. Washington: Government Printing Office. Two volumes, quarto, 545 and 738 pages.

many scattered facts of great interest, which are collected together and utilized in the second volume.

The chief iuterest in the first volume lies in the picture it gives of the life and pursuits of a party which remained for nearly three years far above the Arctic Circle. Two of these years were spent in the active pursuit of the meteorological and geographical work to which the party had been assigned, and the third in hardships and sufferings such as seldom fall to the lot of man. The two years spent in their proper work passed off, apparently, in comfort, cheerfulness, and success; the story of the third year is told very pathetically — with the pathos of the naked truth — in the private diaries already mentioned.

Volume two consists of the scientific appendices, with tables of observations and their discussion. Fort Conger lies in latitude 81° 44′ N., longitude 64° 44′ W. The astronomical observatiens show that the highest northern point reached was 83° 24′, with an uncertainty in the result of not more than one minute of arc.

Experiments were made on the velocity of sound at low temperatures. In all 544 observations were made, and curious unexplained variations appeared in some of the sets. The temperature during the experiments varied from 17.6° F. to—52.6° F. The average decrease of velocity for each degree Fahrenheit was 1.099 feet per second. This differs but little from results obtained at higher temperatures.

The meteorolgical observations are printed *in extenso*, and, as might be expected, many interesting results can be drawn from them. Among these are some conclusions as to polar waves of pressure on which General Greely enlarges somewhat in his *American Weather*, and, while these results are confessedly inexact, he thinks they indicate a new and important line of study which promises to aid in long time predictions of the weather.

The average pressure at Fort Conger was 29.874 inches, at mean sea level. The principal maximum of monthly pressure was 30.137 inches (April); the principal minimum was 29.757 (July). A secondary maximum and minimum fell in Novem-

ber and February. The principal diurnal maximum fell at 5 A. M. (Washington mean time), and the minimum at 1 P. M. The secondary maxima snd minima were at 6 P. M. and midnight. The mean diurnal range was a little less than 0.01 inch. The absolute time for these critical diurnal points is about the same for all arctic stations. The absolute maximum observed was 31.00 inches (Apri 19, 1882) and the minimum 28.97 inches (Feb. 19), giving a range of 2.03 inches of mercury.

The annual mean temperature for three years was —3.9° F.—the lowest known mean on the earth's surface. The mean during the absence of the sun (4½ months each year) was —30.6°. By considering other observations about the pole, Gen. Greely reaches the conclusion that the mean temperature at the pole is probably about —10° if the pole is surrounded by land of considerable extent. The maximum monthly temperature was 37.1° (July), the minimum —40.1° (February). The highest temperature in the shade was 53.0° (June 30, 1882), the lowest —63.1° (February 3, 1882). A lower temperature (—70.8°) was observed in 1875–6 by the English party.

The direction and velocity of the wind were controlled to some extent by the topography about the station. The velocity at Fort Conger averaged, at an elevation of 50 feet above sea-level, only 2.64 miles per hour, but on Bellot island, 1553 feet above the sea, it was over three times as great, and on Dutch island, 25 feet above the sea but freely exposed, it was over twice as great. During the long absence of the sun calms averaged 17 hours daily, but during the continual sunlight only one hour daily. The highest hourly velocity at the station was 63 miles (January 16, 1882). The resultant direction was S. 64° E.

Storms were not especially frequent or severe. The worst was on January 16, 1882. It probably was the same as that felt at Point Barrow on the days immediately preceding.

The mean cloudiness was 50 per cent. The cloudiness during the absence of the sun was decidedly less (34 per cent.). The greatest cloudiness naturally fell in the warmest months (74 per cent. in July and August).

Great care was needed and expended in measuring the pre-

cipitation. It was very scant, aggregating only 3.95 inches the first year and 3.82 the second. The greatest monthly fall was in July, 1882 (1.01), and the smallest (0.11) in February and November, 1882, and June, 1883. Considerable water was precipitated as hoarfrost. Evaporation in winter was extremely small.

The excess of solar radiation temperatures (black-bulb thermometer *in vacuo*) over those in the shade increases rapidly from the appearance of the sun, when it averages 37.3°, to May, when it reaches 70.4°. It then decreases rapidly and steadily until the end of the season (October) when it is only 11.7°. The change in May is due to the melting of the snow, the thawing of the ground, and the breaking up of the ice. The maximum reading of the black-bulb thermometer was 124.5° (May 31, 1883). The greatest difference between the black-bulb and the ordinary thermometers was 96° (May 5, 1883).

In the case of two or three landslides, where fresh surfaces were exposed, it was found that the soil was only a few feet in depth and rested on solid ice. The soil was thawed in these cases to a depth of two or three feet and was covered by a scanty flora.

The mean temperature of the sea-water at the surface decreased from 38.7° at Disco island (66° N.) to 26.9° at Fort Conger. At the latter station the temperature was 29.3° at the depth of 33 feet.

The auroras were neither numerous nor especially remarkable; only the brightest were accompanied by magnetic disturbances. They sometimes gave appreciable light, and in one instance cast a shadow, but no sound was heard from them.

Meteorological observations were continued in the retreat and at Camp Clay where the party awaited their rescuers for ten months. Notwithstanding sufferings from starvation and cold, generally so severe as to prove fatal, the observations were continued up to within two days of the arrival of the relief.

The magnetic observations were taken with especial care and conscientiousness by Sergeant Israel. They are of great interest because Fort Conger lies to the north of the magnetic pole, nearly between it and the geographical pole. These observa-

tions are discussed by Mr. C. A. Schott of the Coast Survey, whose skill in this direction is well known. The magnetic declination proves to have been 100° 13.6′ W. Between 1876 and 1883 it had diminished apparently at the rate of 10′ per year. The average diurnal range was 1° 6′. The dip was 85° 1′ N.; in 1875–6 it was 84° 50′. In British units for the epoch 1882.2 the horizontal force was 1.118, the vertical force 12.822, and, consequently, the total force was 12.870.

At Fort Conger high water follows the moon 11h. 33m., and the mean difference between high and low water is 52 inches. An increase of one inch in the pressure of the atmosphere reduced the half-tide level on the average by 11.4 inches.

ERRATA.—On page 561 of the last volume, in the fourth line from the top, instead of "fourteen per cent." read *four per cent.*, as may be seen from Table II. In the first equation on page 555, the first member should be a lower case *v*.